

A GRAPHIC COLOR RASTER SYSTEM FOR APPLICATIONS IN GEOSCIENCE

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1981.



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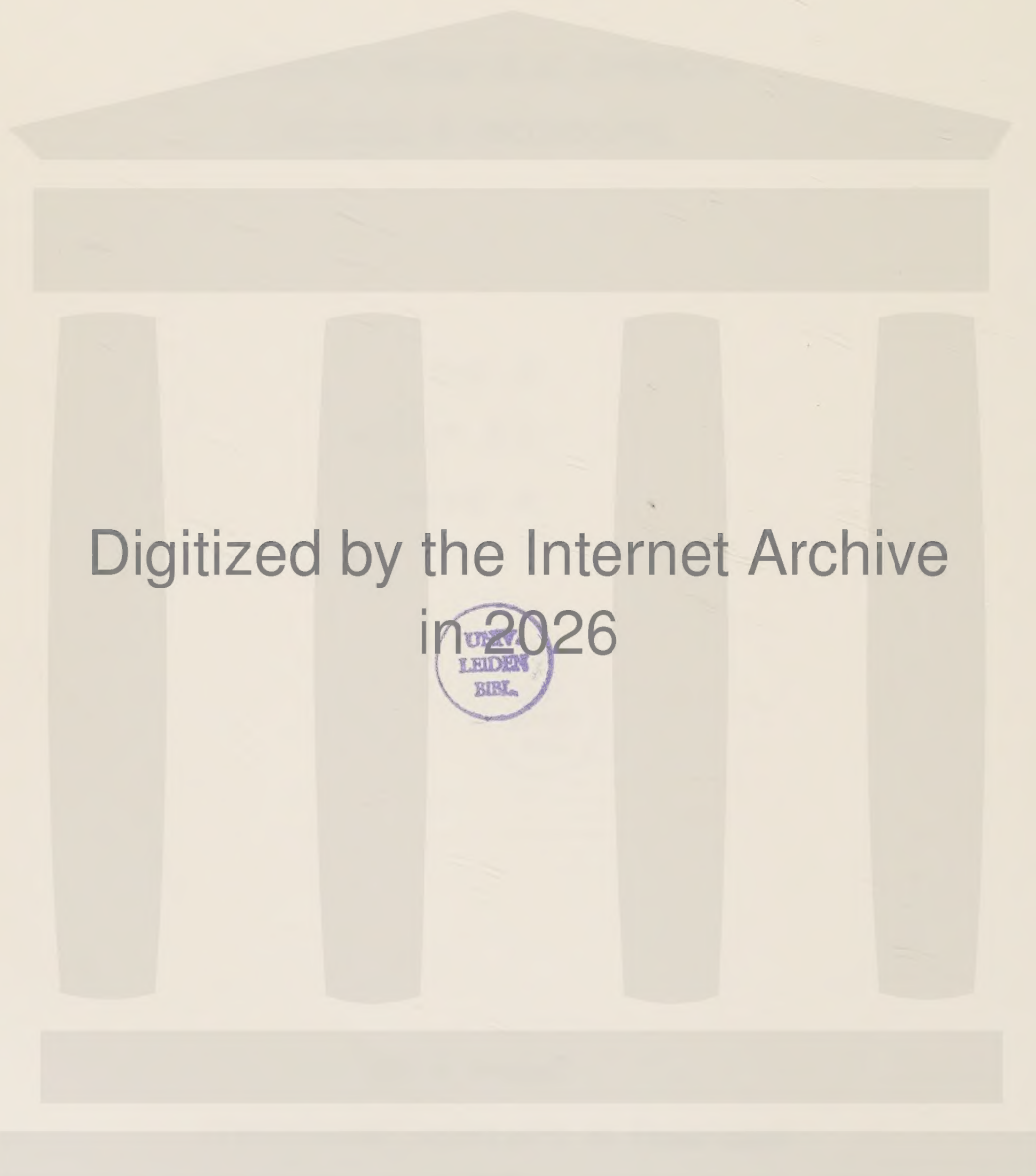
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Report 5/1981

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LUTEDX/(TEEM-1010)/1-17/(1981)



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INTRODUCTION

It is well known that written information is often much easier to comprehend if it is presented in the form of a drawing. This is due to the fact that the eye is used to assess complicated images rather than to read alphanumeric characters. Since the eye can extract relevant information from complex images quickly, pictorial representations of large amounts of data are often superior to the written word or large tables of data. Further, due to the ability of the eye to perceive color, the information content of an image can be greatly increased by using shades of color. This is the reason for the recent rapid growth of computer graphics, preferably in color.

This also applies to geoscience, where large amounts of data usually are presented in the form of maps. Even here the use of colors adds a further dimension which makes it possible to increase the number of parameters or measurement data to be presented.

Until recently colored maps were prepared manually. Because of their complex information contents it seems to be advantageous to let computers take over this time-consuming task. However, to realize this scheme, a computer system including input and output peripherals able to handle colored maps is required.

The purpose of this article is to give a short description of a realization of such a system which is presently in use at the Department of Electrical Measurements at the Lund Institute of Technology, Lund, Sweden. Both the hardware and the software used are mentioned briefly. At the end a few examples are included which illustrate the application of the system in geoscience.

SYSTEM BLOCK DIAGRAM

The color raster graphic system used at the Department of Electrical Measurements, Lund, is described in the block diagram in Figure 1.

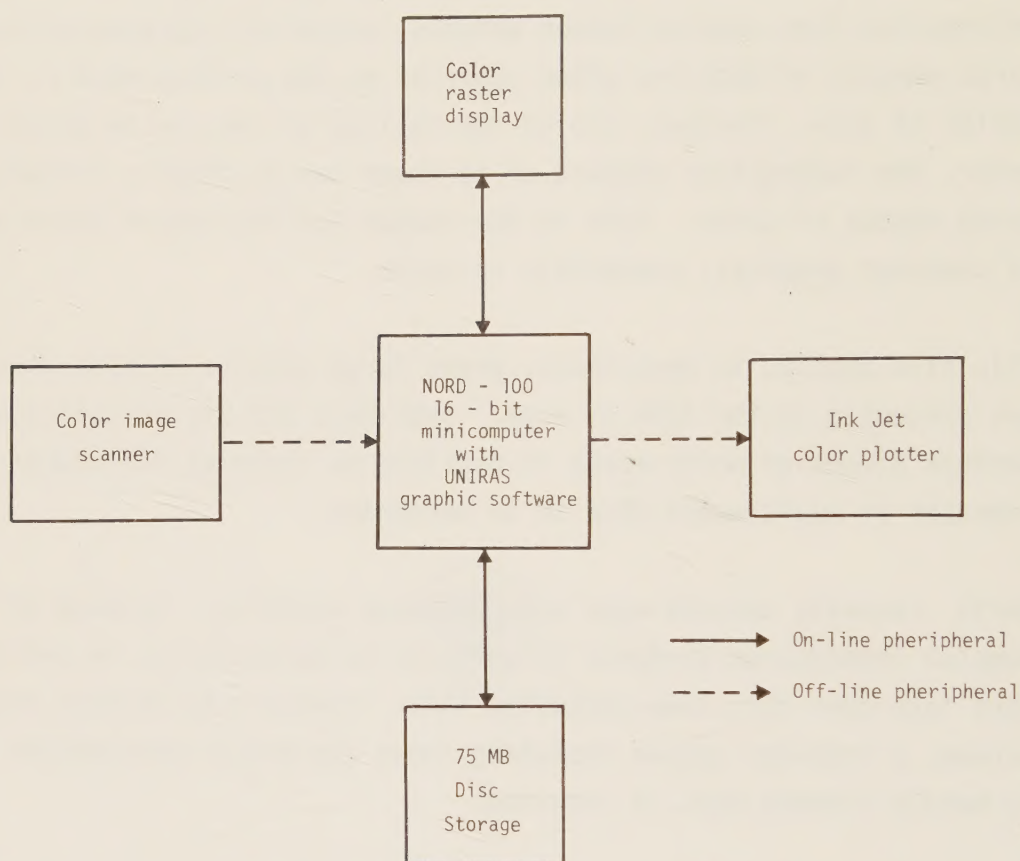


Figure 1. A block diagram of the color raster graphic system used at the Department of Electrical Measurements, Lund, Sweden

The input/output hardware of the system consists of a color image scanner and a color ink jet plotter which both have been developed at the Department (Nilsson & Nygren 1981a, Bladh 1979 and 1980). At the moment they are used as off-line peripherals to a NORD-100 minicomputer with magnetic tapes as intermediate storage media. In addition to this a Lexidata color raster display allows interactive processing of the images in the computer.

The graphic system software is a UNIRAS raster graphic software package (Jern 1981). It is not only used to create images but also to provide the software necessary to drive different types of peripherals.

The color scanner, the interactive color CRT system, and the color jet plotter in conjunction with UNIRAS software represent a powerful graphic color raster system. For example, in this system geological measurements or other parameters can be added to a base-map produced by the scanner. For a preview, the resulting image can be presented on the color CRT system. Here corrections can be entered, if necessary, before the image is reproduced on the color jet plotter or some other raster output device.

THE INK JET COLOR PLOTTER

As shown in Figure 2 the ink jet color plotter system consists of three basic units: a computer, a magnetic tape transport, and the plotting unit.

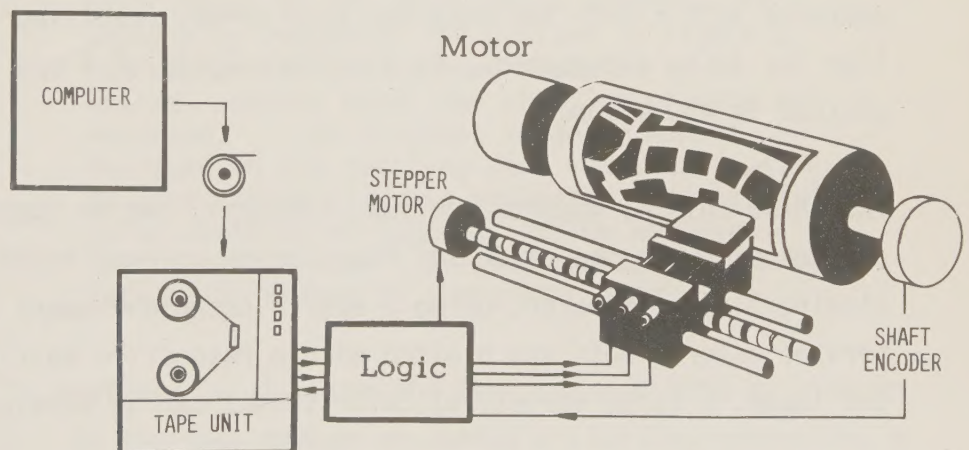


Figure 2. Basic units of the color plotter. The information to be plotted is computed in a suitable format by a computer and stored on a magnetic tape. This tape is then read by a magnetic tape unit into a buffer memory. The read-in and read-out periods of the memory are governed by control circuits, and the read-out signals are used to modulate the intensity of the three ink jets (magenta, yellow, and cyan) mounted in front of the rotating drum carrying the recording paper.

The plotting unit contains a drum onto which the recording medium is attached, and a recording head that can be moved along the drum surface by means of a lead screw turned by a stepper motor. The diameter of the drum is 672 mm and its length 675 mm. It accepts a paper size of 650 x 670 mm².

In the recording head three fine jets of ink are generated with the colors magenta, yellow, and cyan, respectively. The jets are electrically controlled using an especially developed electrode system (Hertz et al. 1972) to allow on/off modulation of the ink jets.

During the plotting the drum normally has a surface speed of 5 m/s, but this can be varied between 2 and 6 m/s. The recording head is advanced in 0.2 mm increments for each drum rotation. In this way the entire surface of the paper is covered by ink jets in parallel lines, perpendicular to the drum axis. A shaft encoder mounted on the drum provides an 0.2 mm resolution along a recording line. Thus each picture element, pixel, in a plot is 0.2 x 0.2 mm².

A picture using the maximum plotting area of 615 x 665 mm² therefore contains 3075 x 3325 ink dots for each color, resulting in >30.6 million ink dots, altogether. At a surface speed of 5 m/s a picture is plotted in 450 seconds.

The three colors, magenta, yellow, and cyan, can be deposited on top of each other on the paper and thus create several solid colors including black. However, using a matrix technique where varying numbers of colored dots are plotted within respective matrix areas of the image, a large variety of color shades can be obtained.

A map or image to be plotted is stored in blocks on magnetic tape by a computer, each block containing the information for one line.

The plotter reads block by block for each revolution of the drum during the plotting operation, and thereby generates the control signals to the ink.

THE COLOR IMAGE SCANNER

The color image scanner (Nilsson and Nygren 1981a) was especially developed to be directly compatible with the ink jet color plotter. Therefore, it physically resembles the plotter with the recording head being replaced by an optical scanner head, (cf. Figure 3).

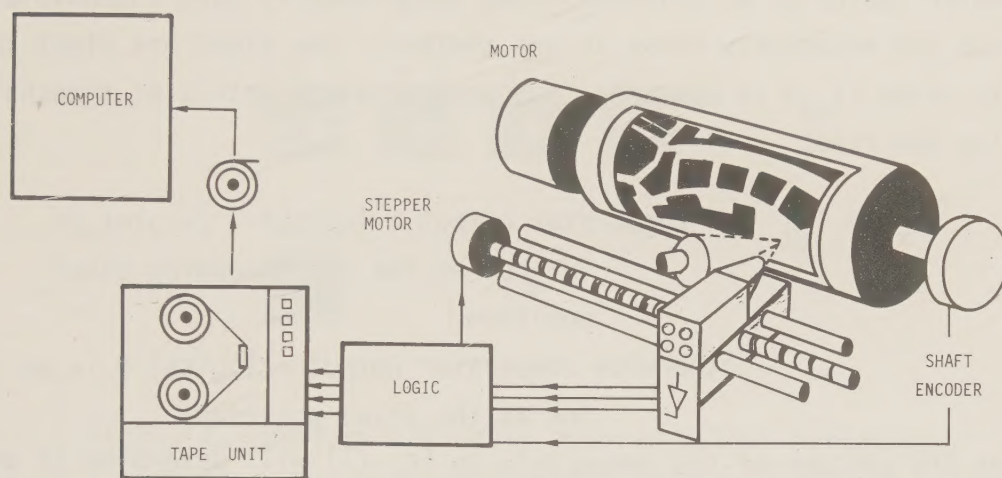


Figure 3. Basic units of the color image scanner. It physically resembles the plotter in Figure 2, but has the recording head replaced by an optical scanner head, and the flow of data is reversed. - An original image or map is fastened on the rotating drum and scanned line by line. Each pixel is separated into its tri-color contents of magenta, yellow and cyan, and converted into a bilevel representation before it is stored on a magnetic tape.

The original is fastened on the drum and then scanned line by line in 0.2 increments. In the same manner as during a plotting operation, a shaft encoder on the rotating drum yields the resolution along a scan-line. In this way the original image is divided into $0.2 \times 0.2 \text{ mm}^2$ pixels.

The scanner head (Nilsson 1981) provides a color separation of each pixel into its tri-color signal contents of magenta, yellow, and cyan. The intensity of each color is detected using a PIN-photodiode and

thereafter converted into an 8 bit digital number. However, this number has to be reduced into a 1 bit representation to be compatible with the format of the bilevel ink jet plotter. This is achieved using a pseudo-gray scale algorithm based on the ordered dither threshold matrix technique successfully used by Judice et al. (1974) for the display of continuous-tone images on bilevel AC plasma displays (cf. Figure 4). The technique relies on the fact that the pixels in a particular region of a continuous-tone image usually have intensities which are relatively close to one another. The eight bit pixel intensity value (I_{xy}) is compared to a predetermined matrix of thresholds (T_{xy}) using the rule:

$$I_{xy} \leq T_{xy} \quad \begin{array}{l} \text{comparator output} = \text{logical 1 (= plot an} \\ \text{ink dot at the corresponding pixel} \\ \text{position} \\ \text{otherwise comparator output} = \text{logical 0 (= no} \\ \text{ink at the pixel position)} \end{array} \quad (1)$$

Thus the outcome of the comparison in Eq. (1) will determine if an ink dot is plotted or not at the corresponding position in the reproduction. This data is also stored on a magnetic tape using the same format as the plotter.

Normally a 4 x 4 or 8 x 8 threshold matrix is used and the same matrix is repeated throughout the entire image in a checkerboard pattern. Figure 4 shows an example of dither matrices used in a reproduction. The main difference between the ordered dither and other threshold techniques is the spatial arrangement of the thresholds within the matrix (Judice et al. 1974). Ordered dither specifies that the average distance between numerically successive thresholds should be as great as possible, which ensures a high spatial bandwidth in the resulting image. Experiments have shown (Nilsson and Nygren 1981b) that the ordered dither technique gave the best results with an ink jet plotter compared to other threshold matrix methods.

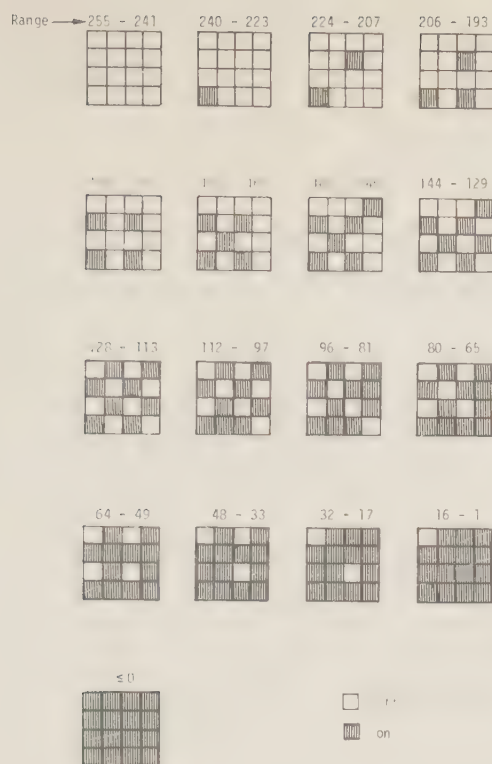


Figure 4. Uniform intensity ordered dither patterns using a 4 x 4 threshold matrix.

THE COLOR RASTER DISPLAY

The Lexidata Color Raster System is a 640 x 512 resolution color monitor with internal memory. The Lexidata System is connected to the minicomputer through a DMA-channel, which allows fast transfers to/from the Lexidata System. Besides presenting raster pictures in color, the Lexidata System has other features. The system can:

- zoom pictures up to 16 times and scroll them
- store up to 3 bilevel pictures in parallel and display any one or all of them simultaneously
- accept coordinates as input and generate vectors and circles
- accept ordinary ASCII-characters and present them as letters or numbers in different sizes
- send part of memory back to the host computer
- send cursor coordinates back to host computer.

All these facilities make the system suitable for interactive processing of images.

THE UNIRAS RASTER SOFTWARE PACKAGE

The software used in the Nord-100 computer system is a raster graphic software package named UNIRAS. It is a package of subroutines written in FORTRAN IV for the preparation of the raster images in color (cf. Figure 5).

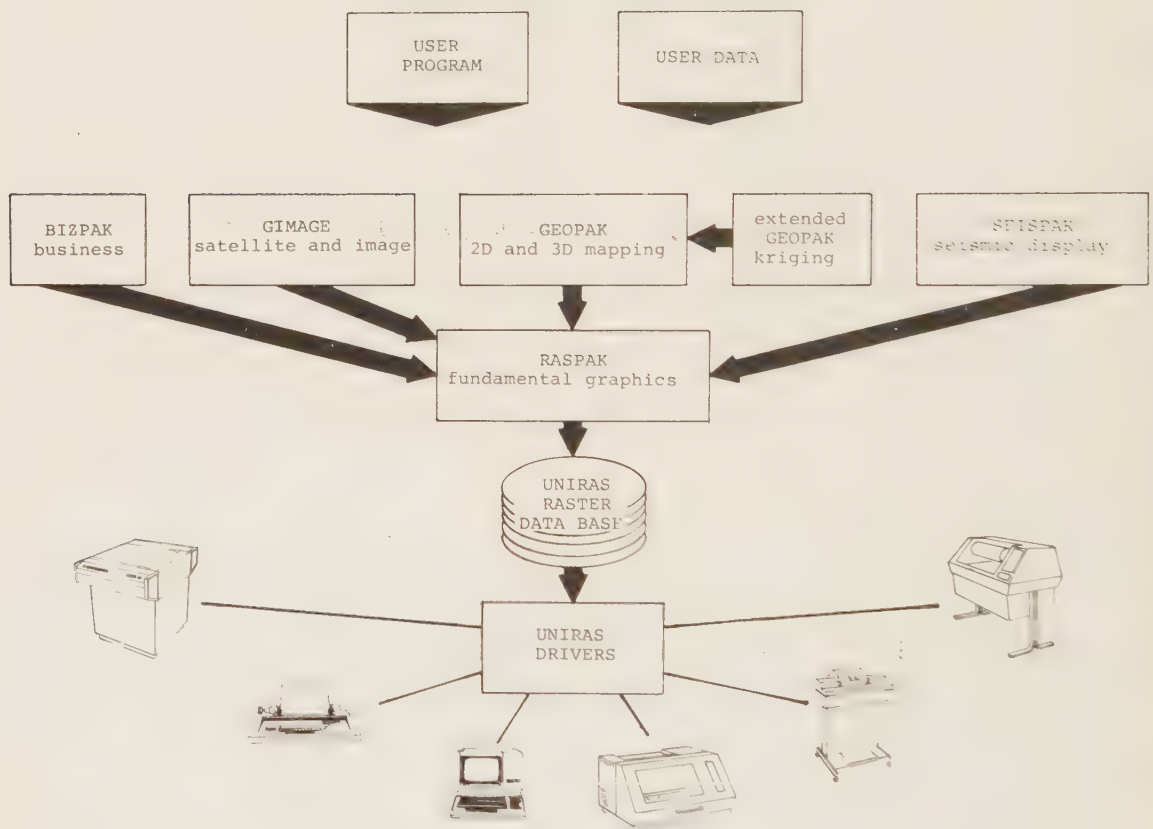


Figure 5. An overview of the UNIRAS raster graphic software package.

UNIRAS consists of the fundamental raster package RASPAK, and additional 4 packages GEOPAK, SEISPAK, GIMAGE, and BIZPAK (Jern 1981).

These packages perform the following tasks:

- RASPAK generates low level graphics consisting of vector drawings and shades areas as well as text and other characters.
- GEOPAK is a mapping package. It offers 2D, 3D and even 4D plotting of maps. The 4D facility uses the x, y, and height as the first three dimensions and color as the fourth. The ability to add a fourth parameter (color) to contour grids permits e.g. the portrayal of complex three-dimensional wave forms where the color eliminates depth perception ambiguities. The extended GEOPAK also includes a complete set of geostatistical subroutines to accomplish semivariograms and kriging in 2D and 3D.
- SEISPAK is a package for seismic data processing, including routines for comparing two different attributes in a seismic section.
- GIMAGE is an application package which manipulates large amounts of input data in non-raster format from e.g. Landsat images and optical scanners. To achieve the continuous-tone to bilevel conversion of the images a threshold technique similar to the one implemented in hardware on the color scanner is used. Compared to the color scanner this conversion to bilevel representation is time-consuming, but necessary as all other input data to the system is saved in bilevel format in the UNIRAS raster database.
- BIZPAK is a business graphic package for generating bar charts, pie charts, and many other special graph textures.

The subroutines from the different packages can be mixed at will in the user application program to generate any desired form of output image.

The main difference between UNIRAS and other software packages presently available is its raster device independence. By calling the software driver for a certain raster device, UNIRAS will automatically maintain the user-defined scale in the picture independent of the pixel size in

the output device. Pictures larger than the maximum format of the output device will automatically be segmented into strips that match precisely for splicing. Another important feature is the user's ability to select black and white or color image representations.

All the above mentioned facilities are included in the UNIRAS software driver for the particular output device used. Thus, the same image generating software can be used for any kind of output device selected by the user. Therefore, in the graphic system described here, an image prepared in the Nord 100-computer can be readily presented either by the Lexidata color display or the color jet plotter.

APPLICATIONS

Figure 6 (first color plate) is an example of the UNIRAS GEOPAK mapping package. The 2D and 3D contour maps demonstrate the effect of switching from a 2D representation into a 3D perspective using the same input data. GEOPAK combines shaded color or gray surfaces with 3D contour grids in a single plot using surface shading technique with a built-in hidden surface algorithm.

This 3D shading surface technique permits the user to fill in grid areas with smooth colored surfaces which eliminates optical illusions that frequently occur when portraying 3D topographic data using an open grid pattern. The software also provides variable viewpoint control, which allows a view of the terrain to be plotted from any view-point selected by the user, ranging from any point on the horizon to directly overhead. Most of the details involved in adding shaded colors to grid plots are handled automatically by the software. Two sets of variable data can be interpolated into gridded data by a GEOPAK interpolation routine so that one set of data can be represented by grid lines (e.g. height) and the other set by shaded colors. This allows essentially for the simultaneous presentation of 4 independent parameters, i.e. 4D-mapping.

Data gathered by satellites can be used to generate pictures in a va-

riety of formats. The data presented in Figure 7 was collected by the Landsat satellite (second color plate). The picture shows the original data after it was manipulated by GIMAGE. The colors red, yellow, and blue, correspond to the following wavelength bands: channel 2 (far infrared), channel 3 (near infrared), and channel 4 (visible light).

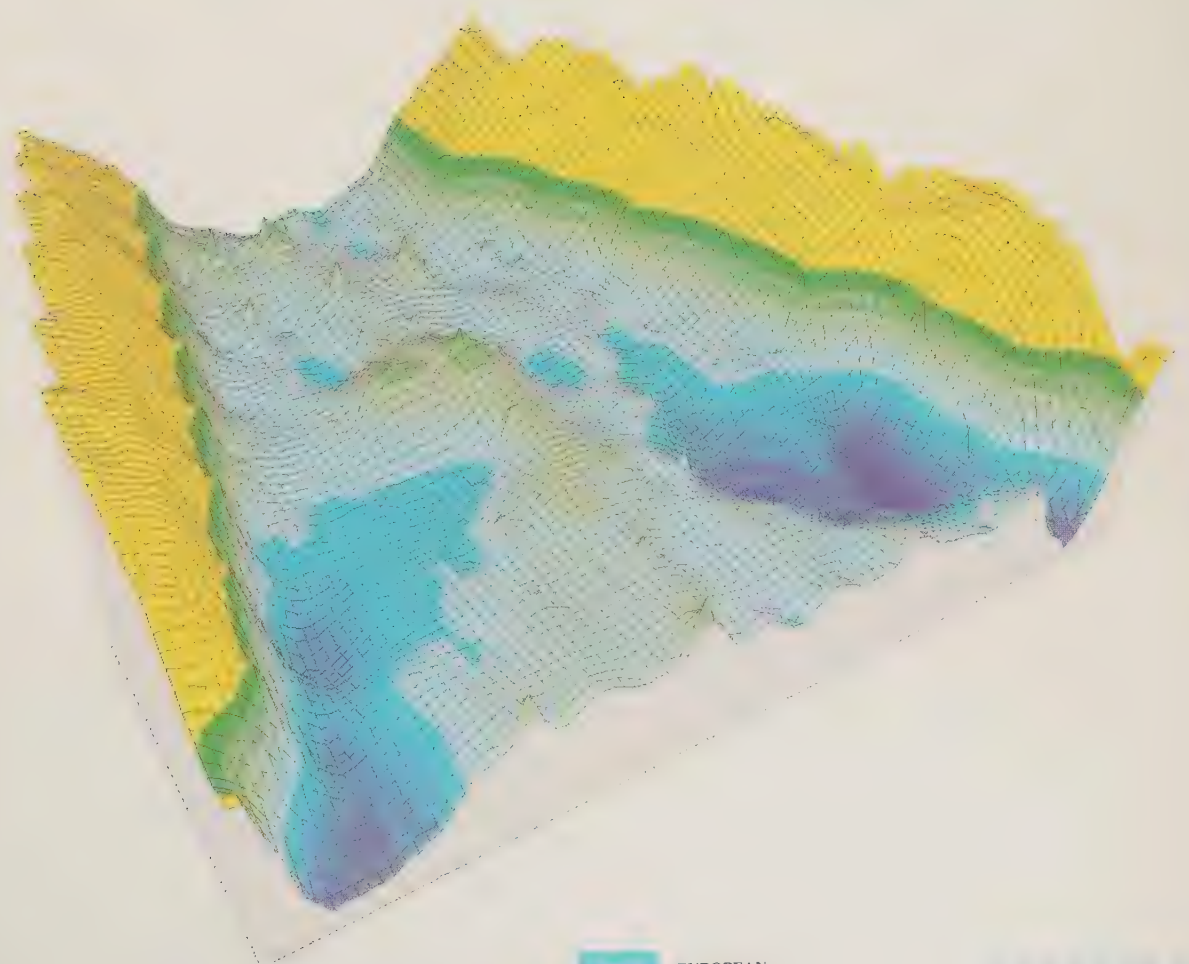
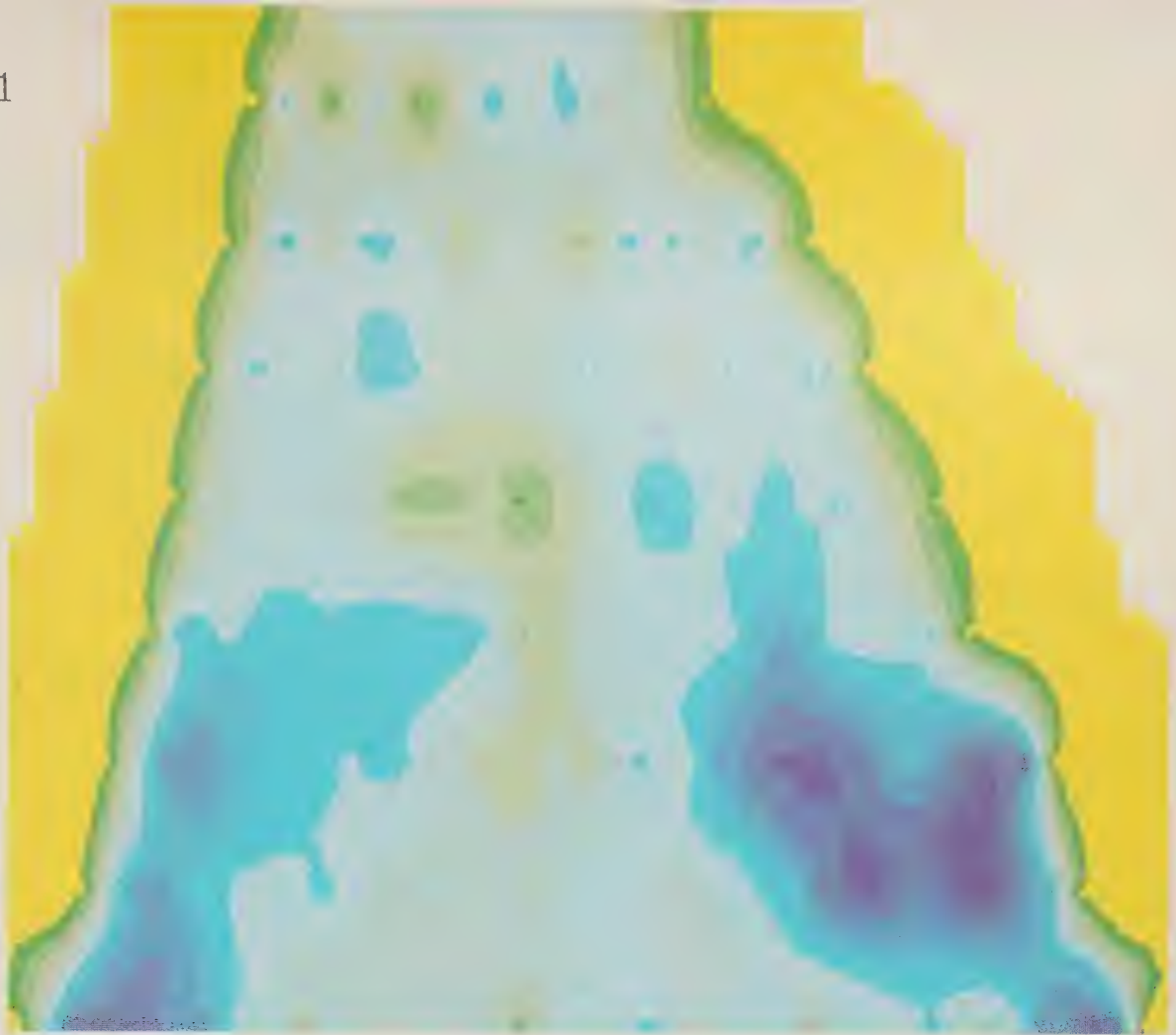
The raw data contains 64 levels of information for every pixel in each of the 3 wavelength bands. This information should be represented in half-tones in each of the three colors. Since the human eye cannot discriminate 64 different half-tones, the number of half-tones is decreased to only 16 per color. Therefore, the number of color shades in this map is $16 \times 16 \times 16 = 4096$.

In several applications where color pictures are used to present results from measurements or statistical data the pictorial display of the input data alone is not sufficient to produce an intelligible output. In geoscience this problem often arises when the input data is taken from a survey over a geographic area. The picture generated by the input data alone will be of little value unless it can be related to a map of the area from which the data has been collected. To overcome this problem a background showing the land area (base-map) is added to the picture. This base-map is often digitized by hand, a time-consuming and hence costly procedure, where the resulting base map often contains only a minimum of details necessary for a few initiated to understand it.

Figure 8 shows the result from an archeological survey where the phosphate concentration in the ground is displayed in an area outside Helsingborg in Sweden. In this case the base map is produced by the color scanner directly from a city planning map. Thereafter the base-map is stored in the UNIRAS data base, and the 2024 phosphate measurements made in this area are converted into a suitable color scale and introduced at their respective coordinates in the base-map. In the figure each phosphate sample on the map has been used for an interpolation of the phosphate concentration over the entire surface.

The base map in the example above was generated in black and white. In

Figure 9 a color background map is generated using the color scanner. This map shows how pie charts can be used to depict the relative content of copper (green), lead (red), and zink (blue) in river sediments. The pie charts are located near the corresponding rivers. The background area, as opposed to the previous figure, is blanked out behind the pie charts to avoid confusion with the background color.



above	0.0
-0.5 -	0.0
-1.0 -	-0.5
-1.5 -	-1.0
-2.0 -	-1.5
-2.5 -	-2.0
-3.0 -	-2.5
-3.5 -	-3.0
-4.0 -	-3.5
-4.5 -	-4.0
below	-4.5





EUROPEAN
SOFTWARE
CONTRACTORS ApS

UNIVERSAL RASTER SYSTEM



PHOSPHATE MAP

RAUS SÖDRA BOSTADSSOMRÅDE
HELSINGBORG KOMMUN, SWEDEN
NOV-DEC 1980

THE SCANNER PROJECT,
DEPT. OF ELECTRICAL MEASUREMENTS, LUND
ANDERS LINDAHL, MUSEUM OF HELSINGBORG
GENERATED BY UNIRAS ON ND NORSK DATA NORD-100

PHOSPHATE DEGREES

above	300
250	300
200	250
150	200
100	150
75	100
50	75
25	50
0	25
20	25
15	20
10	15
5	10
0	5
20	25
15	20
10	15
5	10
0	5
20	25
15	20
10	15
5	10
0	5
20	25
15	20
10	15
5	10
0	5

EUROPEAN
SOFTWARE
CONTRACTORS ApS

UNIVERSAL PASTER SYG

PHOSPHATE MAP

RAUS SÖDRA BOSTADSSOMRÅDE
HELSINGBORG KOMMUN, SWEDEN
NOV-DEC 1980

THE SCANNER PROJECT,
DEPT. OF ELECTRICAL MEASUREMENTS, LUND
ANDERS LINDAHL, MUSEUM OF HELSINGBORG
GENERATED BY UNIRAS ON ND NORSK DATA NORD-100

PHOSPHATE DEGREES

above	300
250	300
200	250
150	200
100	150
75	100
50	75
25	50
0	25
20	25
15	20
10	15
5	10
0	5
20	25
15	20
10	15
5	10
0	5
20	25
15	20
10	15
5	10
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20	25
15	20
10	15
5	10
0	5

EUROPEAN
SOFTWARE
CONTRACTORS ApS

UNIVERSAL PASTER SYG

PHOSPHATE MAP

RAUS SÖDRA BOSTADSSOMRÅDE
HELSINGBORG KOMMUN, SWEDEN
NOV-DEC 1980

THE SCANNER PROJECT,
DEPT. OF ELECTRICAL MEASUREMENTS, LUND
ANDERS LINDAHL, MUSEUM OF HELSINGBORG
GENERATED BY UNIRAS ON ND NORSK DATA NORD-100

PHOSPHATE DEGREES

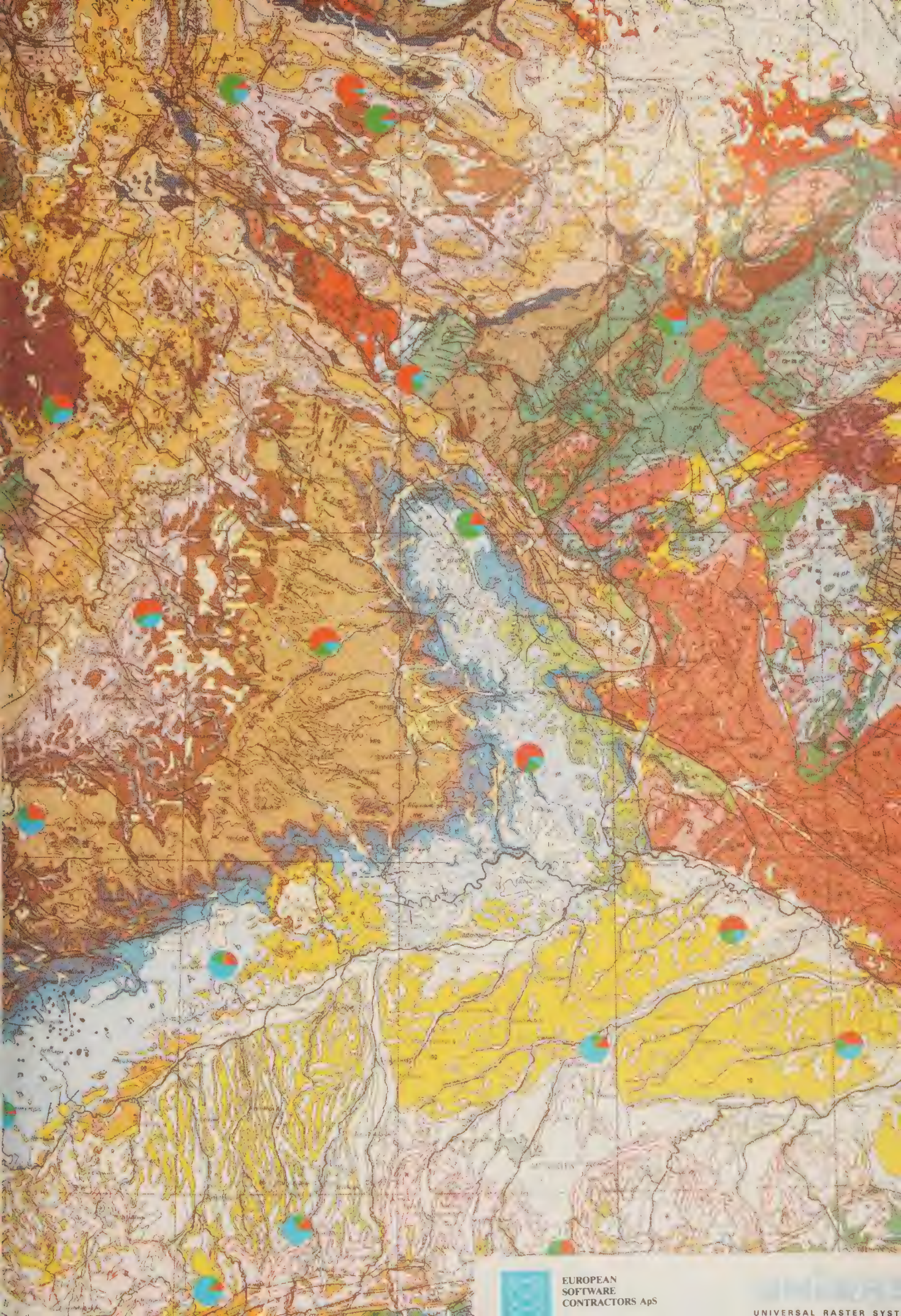
Above	300
275	300
250	275
225	250
200	225
175	200
150	175
125	150
100	125
75	100
50	75
25	50
0	25
-25	0
-50	-25
-75	-50
-100	-75
-125	-100
-150	-125
-175	-150
-200	-175
-225	-200
-250	-225
-275	-250
-300	-275

EUROPEAN SOFTWARE CONTRACTORS ApS

UNIVERSAL PASTER SYSTEM

above	300
250	300
200	250
150	200
100	150
50	100
0	50
-50	0
-100	-50
-150	-100
-200	-150
-250	-200
-300	-250
-350	-300
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-7300	-7250
-7350	-7300





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